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(Not for submission under 37 CFR 1.99)

Application Number	10748587
Filing Date	2003-12-30
First Named Inventor	Robert Steigerwald, et al.
Art Unit	1753
Examiner Name	
Attorney Docket Number	132743

U.S.PATENTS

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	1	SHINOHARA, H.; KIMOTO, K.; ITAMI, T.; AMBOU, T.; OKADO, C.; NAKAJIMA, K.; HOJO, S.; OWADA, K.; KUNIYOSHI, M.; SATO, Y.; "Development of a Residential Use, Utility Interactive PV Inverter With Isolation Transformer-less Circuit-Development Aspects", Photovoltaic Energy Conversion, 1994., Conference Record of the Twenty Fourth; IEE Photovoltaic Specialists Conference-1994, 1994 IEE First World Conference on, Vol..: 1, 5-9 Dec. 1994, Pages: 1216-1218 vol. 1	☐

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Signature	/ANN M. AGOSTI/	Date (YYYY-MM-DD)	2006-04-24
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Development of a Residential Use, Utility Interactive PV Inverter with Isolation Transformer-less Circuit---development aspects

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Abstract

A 3kW residential use, utility interactive PV inverter with isolation transformer-less circuit has been developed. Aiming at cost effective, compact and highly efficient PV inverter, a prototype inverter was fabricated and tested. In order to improve efficiency, AC reactors and other components were specially designed and evaluated. So far, conversion efficiency of 94.5% was attained. Aimed cost of the inverter is ¥50/Watt on the basis of 3,000 units/month production.

Introduction

In sufficiently electrified areas, it seems feasible to utilize dispersed type PV systems which are connected to the utility glid. [1] [2] The research and development of utility-interactive PV inverters has been conducted since 1986. [3]

A PV inverter with isolation transformer-less circuit is now developed from 1993 to 1995. The development is under way after the compietion of former development of "high frequency isolation type PV inverter". [4]

These R&D are supported by the New Energy and Industrial Technology Development organization (NEDO) as a part of New Sunshine Project. In this R&D, key issues listed below are pursued.

(1) Effective cost and compactness
(2) High reliability
(3) High efficiency and low distortion of output power

In order to realize a cost effective and compact system, a PV system which allows reverse-directionai power flow without battery energy storage devices was selected as a basic concept. A prototype PV inverter was designed and manufactured as a basis for an improved type inverter to be fabricated this year.

In this paper, main features of the inverter with isolation transformer-less circuit and some test resuits are reported.

Circuit configuration

Main circuit configuration

Main circuit configuration is shown in Fig. 1. Table 1 shows main ratings of the isoiation transformer-less PV inverter.

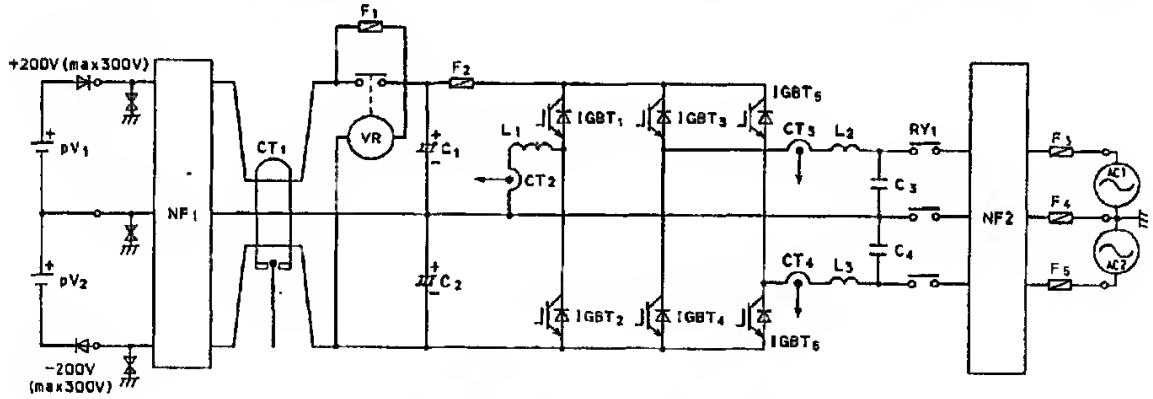

Fig. 1 Main circuit configuration

CH3365-4/94/0000-1216 $4.00 © 1994 IEEE

First WCPEC; Dec. 5–9, 1994; Hawaii

Table 1 Main ratings of transformer-less PV inverter

a. Output Capacity	3kVA
b. DC input voltage	300V×2series
c. AC output voltage	101/202V singie phase, 3 wires
d. power factor	≧0.95
e. control type	self commutated
f. aimed conversion efficiency	95%

DC interface circuit

DC interface circuit consists of DC surge absorbers and DC capacitors. PV input is used in 2-series with the neutral line to be grounded at AC distribu-tion transformer side. DC leakage current is detected with a zero-phaze current transformer. Charging current of DC capacitor is monitored and protected against DC over current of the DC capaci-tor.

Inverter circuit

In the inverter, voltage is modulated in PWM frequency. Switching loss is estimated and PWM frequency was optimized to be 16.7kHz, avoiding audible noise.

IGBTs are used as high frequency switch-ing device.

AC reactor was made optimizing the core material and magnetic flux density.

AC interface circuit

Output switch, surge absorbers, EMI filters and output fuses are used in AC interface circuit. Output current is measured to be used as current feedback and over current protection.

Control/protection circuit configuration

Fig.2 shows a block diagram of control/ protection circuit.

Software is used to do functions listed below.

a. Sequential control
b. Maximum Power Point Tracking (MPPT)
c. Input voltage control
d. Reference sinusoidal wave output
e. Detection of failure, abnormal condition
f. Prevention of output voltage accumlation

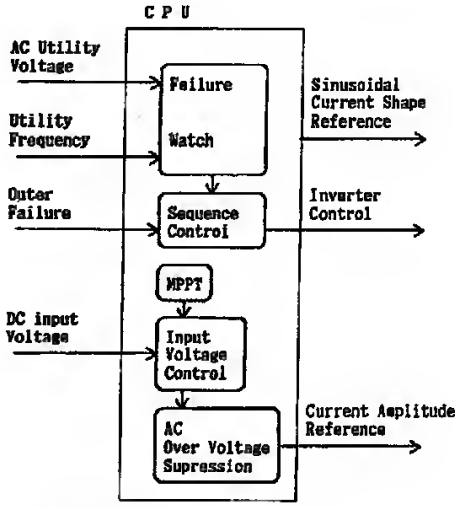

Fig.2 block diagram of control/ protection circuit.

Table 2 Protection Items

Over voltage detection
Under voltage detection
Over Frequency detection
Under Frequency detection
Islanding prevention
a. passive method: voltage phase jump detection
b. active method : slide mode frequency shift [5]

Factory test

Conversion efficiency

Conversion efficiency reached at 94.5% which is still 0.5% lower than the aimed value. Fig.3 is the conversion efficiency of the PV inverter. The main measures taken to improve conversion efficiency is listed below.

(a) Use of thin silicon-steel core for the DC reactors.
(b) Minimized loss design of IGBT
(c) Adjustment of switcing frequency
(d) Refinement of gate resistance and output current control wave shape

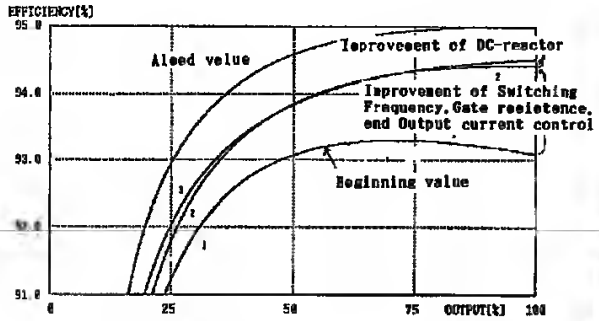

Fig.3 Improvement of conversion efficiency

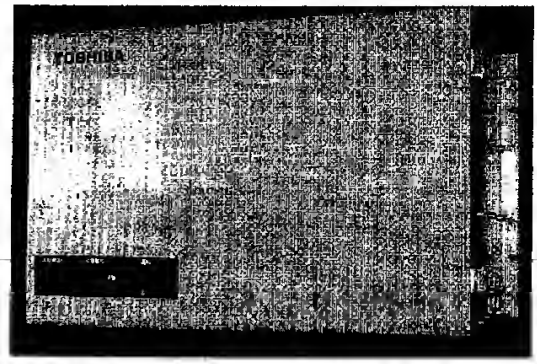

Fig 4 outline of the PV inverter

DC current outflow

Reduction of DC outflow from the inverter to the utility grid is one of main issues for utility safety. DC current outflow is detected with hall effect type current transformers with self compensation windings on the iron core. The aimed value is less than 0.3%, and the temporal measured data is between 0.09% and 0.62% which is to be reduced.

Size and weight

Size and weight of the prototype PV inverter are shown in Table 3. The improved type is to be smaller than these dimensions. Fig.4 is outline of the prototype PV inverter.

Table 3 Inverter size and weight (prototype)

Size	400mm (W) ×240mm (L) ×270mm (H)	
Volume	0.026m^3	(Aimed: 0.019m^3)
Weight	20kg	(Aimed: 18kg)

Output current distortion

Total harmonic distortion is 0.83% at 100% output. Table 4 is measured harmonic components.

Table 4 harmonic components

(at output power of 100%)

	output current distortion (%)	
3rd	0.56	
5th	0.39	
7th	0.36	
9th	0.27	
11th	0.09	
13th	0.07	
total	0.83	(aimed: ≦5%)

Conclusion

A 3kW residential size, utility interactive PV inverter with isolation transformer-less configuration is now developed which complizes Japanese utility interaction guideline. Efficiency of 94.5 % was attained so far, and the output current shape shows low distortion characteristics. An improved type inverter is now designed and to be tested this year.

Evaluation results including cost which aims at ¥50/W on the basis of 3,000 units per month production is to be reported in the next paper.

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(1) H. Kobayashi et al. "Problems and counter-measures on safety of utility grid with a number of small-scale PV systems", 21th IEEE PVSC, 1990

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Acknowledgement

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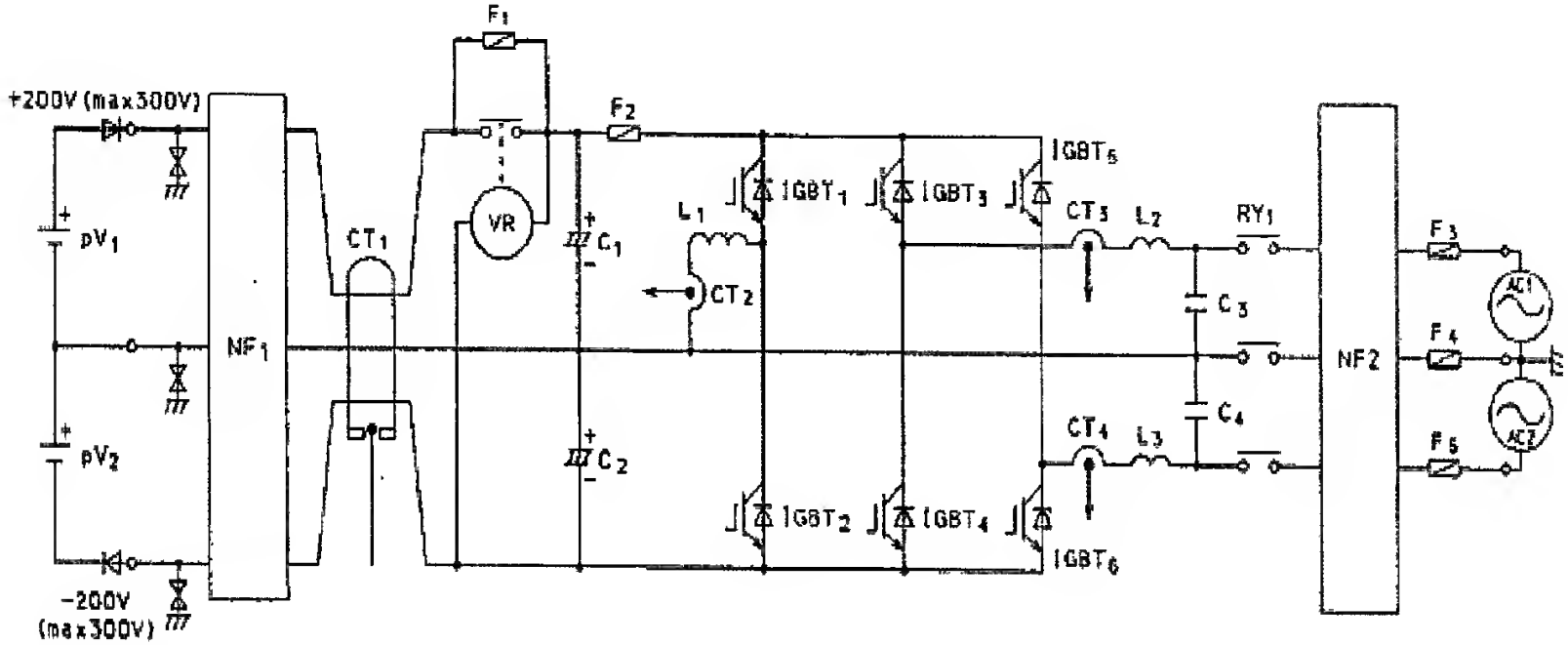

A design from Toshiba

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